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(54) Medical communication system

(57) Medical communication system adapted to perform communication between two units 2,4, at least one of said units is adapted to be implanted in a human or animal body, using one active channel of a number of communication channels, the system comprises monitoring means 10 adapted to monitor the communication channels. All channels not presently used for communication between the units, called passive channels, are continuously monitored by the monitoring means concurrently with the performed communication and the result of said monitoring is stored in a register table provided with one register for each communication channel.

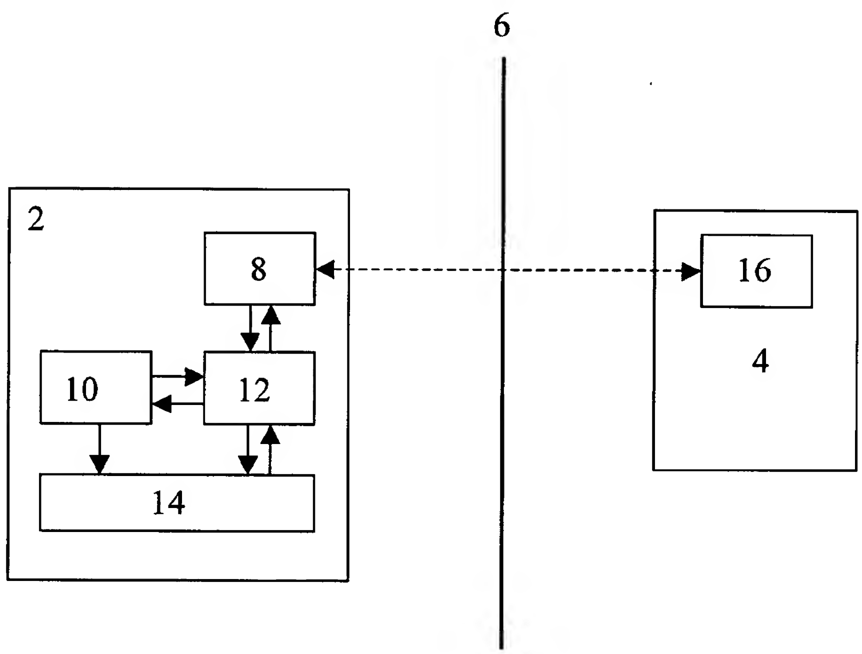

Fig. 1

EP 1 228 782 A1

Description

Field of the invention

[0001] The present invention relates to a medical communication system and to a method in a medical communication system according to the preambles of the independent claims.

Background of the invention

[0002] In RF coupled systems, which are perhaps the most commonly employed communication systems in modern implantable device systems, information is transferred from a transmitting coil to a receiving coil by way of a radiofrequency carrier signal. The carrier signal is modulated with the data that is to be transmitted using an appropriate modulation scheme, such as phase shift keying (PSK), frequency shift keying (FSK), or pulse position modulation (PPM), among numerous others. The modulated carrier induces a voltage in the receiving coil that tracks the modulated carrier signal. This received signal is then demodulated in order to recover the transmitted data. Because the stainless steel or titanium can commonly used to hermetically enclose an implanted device acts as a low-pass filter for the transmitted RF signals, attenuation increases as frequency is increased. Devices currently on the market have a maximum frequency of less than 200-kHz. Also, the transmitting range has been limited to 2- to 3-inches or so.

[0003] Depending upon the type of modulation and demodulation used in an RF communication system, the data or bit rate cannot exceed a predetermined fraction of the carrier frequency; otherwise, the ability to reliably distinguish between modulation representing a digital (binary) "1" from a digital "0" is compromised. Schemes are known which encode digital data to transmit more data per unit time and reduce implanted device current drain. However, at very high data transmission rates, the current drain would be very high.

[0004] RF communication programming units typically interface with the implanted device through the use of a programming head or programming paddle, a handheld unit adapted to be placed on the patient's body over the implant site of the patient's implanted device. In some cases, a magnet in the programming head effects reed switch closure in the implanted device to initiate a communication session (this is a safeguard against accidental programming of the device; otherwise, reed switch closure has little meaning as far as communication of information). Thereafter, uplink and downlink communication takes place between the implanted device's transmitter and receiver and a receiver and transmitter disposed within the programming head.

[0005] A newly proposed standard for Medical Implant Communications Service, MICS, states that a number of radio communication channels within a certain frequency range can be used to establish a communication link between an implanted device and an external unit, or between implanted devices. According to the standard one communication link, i.e. communication between two devices, is not allowed to use more than one channel at a time. If a channel becomes unusable of some reason the system can switch to another of the specified channels. Before a new channel can be accessed, the channel shall be monitored in a manner described by the standard in order to avoid collisions.

[0006] To avoid accessing a channel in use, a MICS system shall, according to the standard, monitor the channel within the frequency range allocated for MICS information transmission before attempting to establish contact. The earmarked frequency range for communication is divided into N channels. The standard states that a channel shall be monitored for a period of at least 10 ms within 5 seconds prior to access, to ensure it is not occupied. In a noisy environment the channel in use can become inaccessible and a rather frequent channel switching can be necessary due to circumstances beyond the control of the operator.

[0007] If a search fails on one channel, e.g. due to too high noise level or if the channel is already in use, a 10 ms search period must be started to monitor a new channel and the procedure must be repeated until a noise-free channel is found. Repetitive searches might result in several 10ms search periods before a noise free channel is found which lowers the transmission stability of the communication link.

[0008] Furthermore, the standard prescribes a procedure how to investigate a channel before accessing it. In short a frequency monitoring is performed by incorporating a mechanism in a medical implant transmitter for monitoring the channel or channels that the MICS system devices intend to occupy. The monitoring system antenna shall be the antenna normally used by the transmitter for a communications session. Before a medical implant transmitter initiates a MICS communication session, the following access criteria must be met:

(1) The monitoring system bandwidth measured at its 20 dB down points must be equal to or greater than the emission bandwidth of the intended transmission.

(2) Within 5 seconds prior to initiating a communications session, circuitry associated with a medical implant transmitter must monitor the channel or channels the MICS system devices intend to occupy for a minimum of 10 milliseconds per channel. Before transmitting on an alternate channel, the channel must be monitored for a period of at least 10 milliseconds.

[0009] A similar way of detecting carrier frequencies is also included in a standard draft version from European Telecommunication Standard Institute (ETSI). The European standard covers radio equipment in the fre-

quency range 402 MHz to 405 MHz for Ultra Low Power Active Medical Implants and Accessories. Within this frequency range the maximum permitted emission bandwidth for each channel is set to 300 kHz, i.e. 10 channels side by side starting from 402 MHz.

[0010] US-6,150,951 relates to a medical telemetry system with wireless and physical communication channels. The system includes an apparatus for monitoring a transmission activity in a pre-given channel range for determining possible channels in use, so that the transmission channel is assigned to the transmitter in accordance with the determined channels in use. Before a transmitter will be used for transmission purposes in combination with a receiver, the receiver monitors the "on air activity" in its environment for any transmission activity in a certain channel range assigned to the receiver. This phase is called the "scanning phase". The receiver thus determines which channels are in use, e. g., by any other transmitter or by other functional units. The receiver may e.g. comprise a synthesizer receiver unit for stepping through a predefined channel range and for measuring the received signal strength on each of the channels. When the received signal strength of a certain channel exceeds a certain predefined value, the receiver will treat this channel as being in use.

In this known device the transmitter is designated a specific channel during the scanning phase that it then uses during operation. One drawback with this system is that it is unable to handle a situation when e.g. noise disturbs the used specific channel during operation. The reason is that the scanning phase is performed before the transmitter will be used for transmission purposes.

[0011] The object of the present invention is to set forth a technique that minimizes the time spent to decide which new channel to be used once the currently used channel becomes unusable in order to recognize an available channel for a fast channel switchover.

Summary of the invention

[0012] A medical communication system and a medical communication method according to the characterizing parts of the independent claims achieve the above-mentioned object.

[0013] Preferred embodiments are set forth in the dependent claims.

[0014] Thus, instead of interrupting the transmission once the current channel is discarded and wasting time during the one or several 10 ms search periods the new channel(s) being monitored the monitoring process runs continuously and concurrently with the normal transmission process.

Short description of the appended drawings

[0015] Figure 1 shows a simplified block diagram of a medical communication system according to the present invention.

Figure 2 shows a flow chart illustrating a method in the medical communication system according to the present invention.

Detailed description of preferred embodiments of the invention

[0016] Figure 1 shows a simplified block diagram of a medical communication system according to the present invention.

The medical communication system comprises two units wherein at least one of the units is adapted to be implanted in a human or animal body. The figure discloses a system comprising an external unit 2 and an internal unit 4 separated by the skin 6 of the patient. The external unit 2 comprises external transmitter means 8, monitoring means 10, control means 12 and register tables 14. Naturally many other means are included in the external means, but these are omitted when describing the present invention, as they are not directly involved when practising the invention. Persons skilled in the art are aware of these other means, among which can be mentioned energising means, memory means, display means, data entering means e.g. a keyboard, etc. Also omitted is a programming head, which inter alia includes transmitting coils, used to generate the radio frequency signals. The programming head is connected to the external transmitter means 8 e.g. via an electrical cable and is positioned during transmission on the skin close to the internal unit 4. Naturally other possibilities are possible, e.g. the programming head need not be positioned in the vicinity of the internal unit and the communication between the programming head and the external emitter may be wireless.

Any conventional programming head adapted for the used radio frequencies may be used.

The internal unit 4 is adapted to be implanted into a human or animal body and comprises internal transmitter means 16 arranged to communicate with the external transmitter means 8. The internal transmitter means 16 is provided with all necessary circuitry in order to be able to perform the communication, e.g. a transmitting antenna, modulation and demodulation means.

The internal unit 4 may be any device adapted to be implanted into a human or animal body, e.g. a heart pacemaker, a heart defibrillator, a cardioverter or an infusion pump, and is naturally provided with the necessary means needed to perform its intended purpose. In case of a heart pacemaker the internal unit includes a battery means, pulse generating means, electrode means, control means etc.

[0017] In figure 1 the dotted double-arrowhead line designates the radio frequency communication signal between the units.

[0018] Using one active channel of a number of radio communication channels e.g. in accordance with the above-described MICS system performs the communication between the two units.

[0019] According to the present invention the monitoring means 10 monitors all communication channels in the prescribed frequency range not presently used for communication between the units, i.e. the passive channels. These channels are continuously monitored by the monitoring means concurrently with the performed communication.

[0020] During the monitoring the monitoring means preferably uses the antenna, e.g. the programming head, connected to the transmitter means.

[0021] The intention of the monitoring is to assess the activity in channel using a specific frequency. The activity may be caused by that the channel already is used or by any type of interference, e.g. noise due to electromagnetic interference.

When the activity in the monitored channel is too high that channel is regarded as non-available for communication. The activity of a specific channel may be determined in many different ways. One obvious way is to integrate the signal in the frequency designated to the channel and compare the calculated value with a threshold, wherein if the value is below the threshold the activity is low and the channel is available for communication. If the value is above the threshold the activity of the channel is considered too high to allow secure communication. The result of the monitoring is stored in the register table 14 that is provided with one register for each communication channel. In each register may be stored information reflecting the result of the monitoring, either as a logic value, e.g. OK or not OK for communication, or the analogue value resulting from the integration. Alternatively both these values may be stored.

[0022] When switching to a new channel the control means 12 that initiates the switching may either use a simple criterion that the activity level shall be lower then a threshold, i.e. choose one of the channels having an OK stored in its register. Alternatively the channel is chosen with the lowest analogue value stored in the register table provided that this value is below the threshold. Upon channel switching one of the passive channels that fulfils the above-mentioned criterion becomes active and the presently active channel becomes passive. The channel switching according to the present invention is more or less instantly performed and depends upon which channel switching method that is presently used.

In one channel switching method the messages sent from a transmitter to a receiver includes information about which channel/channels the receiver should switch to. The channel switching is performed either in response of a direct switching command, in response of a command included in the message, or the receiver itself changes to a defined channel if the connection to the transmitter is broken.

Alternately the transmitter and receiver have a predefined channel switching scheme to follow as soon as a channel switching takes place. Thus, if the receiver does not receive a message within a prescribed time or does not receive confirmation of the last sent message the receiver switches to the next predefined channel, naturally provided that the next predefined channel is available for communication.

[0023] According to a preferred embodiment of the present invention all passive channels are monitored for a period of at least 10 ms at least every 5th second.

[0024] The minimum time set for monitoring and the frequency of the monitoring are dependants of requirements set by different standards that of course may be changed, e.g. to a shorter monitoring period and a more frequent monitoring. All these possible changes fall within the broadest scope of the present invention that is defined by the independent claims.

[0025] According to a first preferred embodiment of the present invention the passive channels are monitored using a first monitoring mode where all passive channels are scanned in sequence, wherein each channel is at least scanned each 5th second.

[0026] According to a second preferred embodiment of the present invention the passive channels are monitored using a second monitoring mode where all passive channels are monitored in parallel.

[0027] According to a third preferred embodiment of the present invention the passive channels are monitored using a third monitoring mode where all passive channels are monitored in parallel by using a frequency analysing algorithm. In this embodiment a wide-band signal is created from the received radio signal with a bandwidth equal to the sum of the bandwidths of all N channels. After applying a frequency analysing algorithm, such as the Fast Fourier Transform or a wavelet algorithm, the signal level in all N channels can be calculated simultaneously in on single process. The corresponding activity level in each channel, resulting from the calculation, is then stored in the register table in the same way as described above. The wavelet algorithm is a method for determining the frequency content in an unknown signal by adapting known signals having known frequency contents to the unknown signal so that the unknown signal may be expressed in terms of the known signals.

[0028] When choosing a new active channel different selection criterion may be used when activity information is stored in the register table in the form of OK or not OK.

According to one selection criterion the channel that last received an OK is chosen. According to another selection criterion the channel using a frequency that differs most from the frequency of the presently used active channel is chosen. Naturally combinations of these criteria may be used.

[0029] As indicated above each unit comprises communication means e.g. transmitter coils, adapted to transmit and receive information using said communication channels.

[0030] Figure 2 shows a flow chart illustrating a method in the medical communication system according to the present invention.

The flow chart only schematically illustrates the principles of the present invention.
The illustrated method comprises the following main steps or procedures:

a) Start a communication session between two units, using one active channel of a number of radio communication channels. At least one of said units is adapted to be implanted in a human or animal body.
b) Continuously monitoring the communication channels not presently used for communication, called passive channels, by using monitoring means concurrently with the performed communication. Shown in the left branch of the figure.
c) Storing the result of said monitoring in a register table provided with one register for each communication channel, wherein the result indicates if a channel is available for communication.

[0031] The figure further illustrates (in the right branch) that the active channel is continuously monitored and that a channel switching is performed if it is determined that the active channel is unusable. Upon channel switching one of the passive channels available for communication instantly becomes active.
[0032] According to a preferred embodiment each one of the passive channels is monitored in step b) for a period of at least 10 ms at least every 5th second.
[0033] The present invention is not limited to the above-described preferred embodiments. Various alternatives, modifications and equivalents may be used. Therefore, the above embodiments should not be taken as limiting the scope of the invention, which is defined by the appending claims.

Claims

1. A medical communication system adapted to establish a communication link and to perform communication between two units (2,4), where at least one of said units is adapted to be implanted in a human or animal body, the system being arranged to use a single channel, selected from a plurality of communication channels which can be either active or passive, for establishing said communication link and for performing said communication as the active communication channel during a communication time interval, the other channels being termed passive channels, and further to comprise a monitoring means (10) adapted to monitor said plurality of communication channels, **characterized in that** said passive channels are monitored with respect to their availability for communication by said monitoring means (10) during said communication time interval and that the result of said monitoring is stored in a register table (14) provided with one register for each communication channel, and further **in that** said active channel is continuously monitored by said monitoring means and that a control means (12) performs a channel switching, when determining that the active channel is unusable, to an available passive channel which then instantly becomes the active channel.

2. Medical communication system according to claim 1, **characterized in that** each one of the passive channels is monitored for a period of at least 10 ms at least every 5th second.

3. Medical communication system according to any preceding claim, **characterized in that** said passive channels are monitored using a first monitoring mode where all passive channels are scanned in sequence, wherein each channel is at least scanned each 5th second.

4. Medical communication system according to any of claims 1-2, **characterized in that** said passive channels are monitored using a second monitoring mode where all passive channels are monitored in parallel.

5. Medical communication system according to any of claims 1-2, **characterized in that** said passive channels are monitored using a third monitoring mode where all passive channels are monitored in parallel by using a frequency analysing algorithm.

6. Medical communication system according to any preceding claim, **characterized in that** said monitoring means is adapted to generate an acknowledgement signal when a channel fulfils a predetermined access criterion and to store said signal in a register representing the channel.

7. Medical communication system according to claim 6, **characterized in that**, wherein said access criterion is fulfilled if a value representing the energy content of the signal activity in the monitored channel is lower than a predetermined value.

8. Medical communication system according to claim 7, **characterized in that** the energy content is determined by integrating the signal activity.

9. Method in a medical communication system, wherein the method comprises the following steps:

a) start communication session between two units, at least one of said units is adapted to be implanted in a human or animal body, using one active channel, of a number of communication channels,
b) monitoring the communication channels not

presently used for communication, passive channels, **characterized in that** said monitoring occurs concurrently with the performed communication, and

c) storing the result of said monitoring in a register table provided with one register for each communication channel, wherein the result indicates if a channel is available for communication.

d) continuously monitoring the active channel and performing a channel switching if it is determined that the active channel is unusable, wherein upon channel switching one of the passive channels available for communication instantly becomes active.

10. Method in a medical communication system according to claim 9, **characterized in that** each one of the passive channels is monitored in step b) for a period of at least 10 ms at least every 5th second.

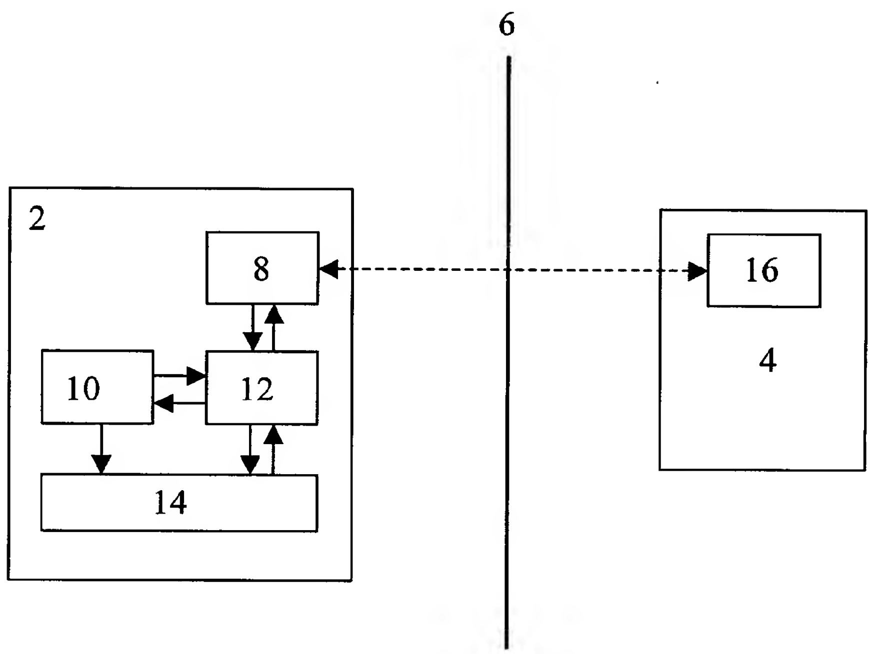

Fig. 1

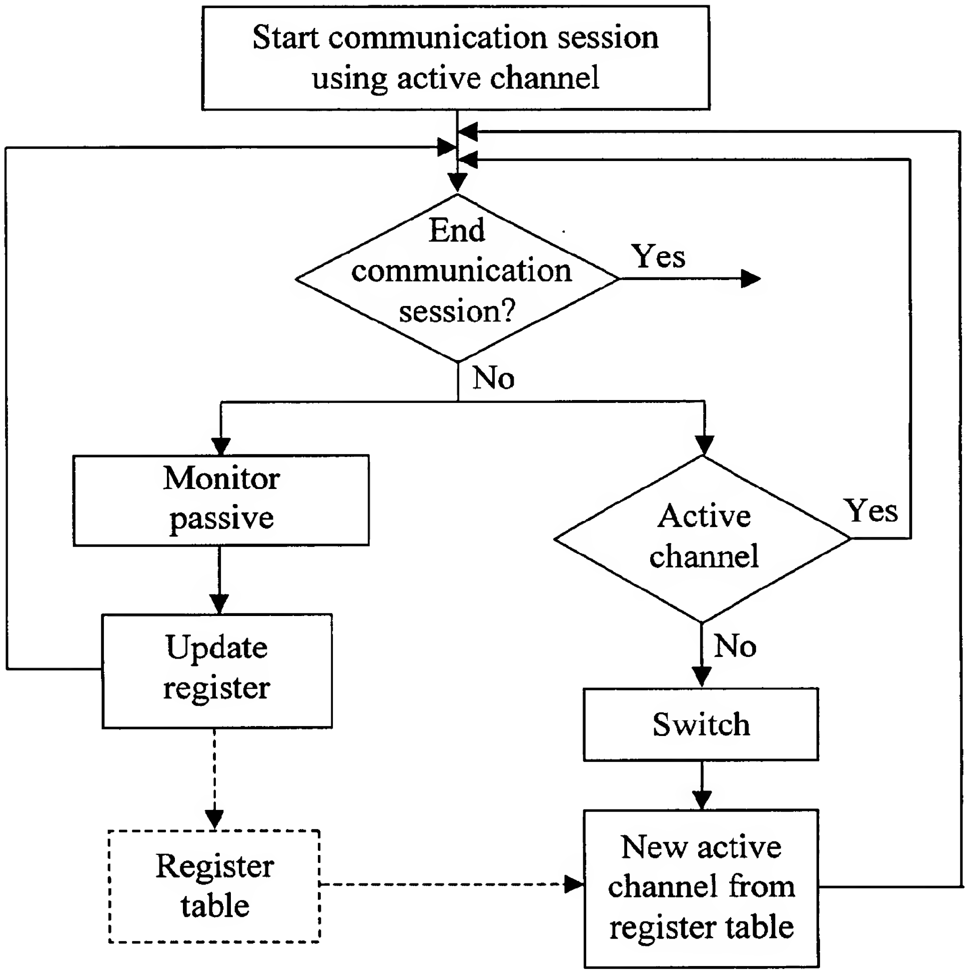
Start communication session using active channel
End communication session?
Yes
No
Monitor passive
Active channel
Yes
Update register
No
Switch
Register table
New active channel from register table

Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 12 6937

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	8 May 2002	Ferrigno, A

CATEGORY OF CITED DOCUMENTS

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